

SHORT COMMUNICATION

Relevance of collected juveniles to the analysis of spider communities

T.E. Sackett^{1,3}, C.M. Buddle¹ and C. Vincent²: ¹Department of Natural Resource Sciences, McGill University, Macdonald Campus, 21,111 Lakeshore Rd., Ste. Anne de Bellevue, Québec, H9X 3V9 Canada; ²Horticultural Research and Development Center, Agriculture and Agri-Food Canada, 430 Gouin Blvd., Saint-Jean-sur-Richelieu, Québec, J3B 3E6 Canada

Abstract. Spider field collections often consist of a high percentage of immature specimens that are not identifiable to species; in many studies these juveniles are discarded and not used in analyses. To evaluate if this practice affects the results of a community study, we sampled foliage-dwelling spiders in two habitats, reared the collected immature spiders until maturity, and identified them to species. We tested if measurements of species richness, evenness, and assemblage composition changed with the exclusion of data from immature specimens by analyzing two datasets: one including mature spiders only, the other including both mature and immature spiders (complete dataset). Nine of the total 49 spider species were collected only as juveniles, but only one of these nine species, *Philodromus praelustris* Keyserling 1880, was common ($\geq 10\%$ of collection). The distribution of individuals among species was more even in the complete dataset than the mature-only dataset, which could either indicate differences in composition or reflect sampling effort. However, species richness estimates were similar regardless of dataset, and there were only small changes in species composition of the samples between datasets, suggesting that there were not important compositional differences between the samples in each dataset. The inclusion of immature spiders in the data in this study yielded the same results that would occur with increased sampling effort.

Keywords: Immature spiders, rearing, biodiversity

In community studies, field collections of spiders often have a high proportion of immature spiders as compared to mature spiders: the percentage of juveniles may reach over 80% of the individuals collected (Brierton et al. 2003; Samu et al. 1997). As a result, the number of spiders that are identified to genus or species level varies; in some studies 70–80% of all specimens are identified (Bostanian et al. 1984; Olszak et al. 1992a, 1992b; Brierton et al. 2003), whereas in others the number is as low as 20% (Mason et al. 1997; Samu et al. 1997). The accuracy to which an immature spider is identified to genus or species often depends on its family: Linyphiidae, Dictynidae, Clubionidae, and some Salticidae are more rarely identified to species when collected as juveniles in foliage studies (Bostanian et al. 1984; Olszak et al. 1992b; Mason et al. 1997), while Araneidae and Thomisidae juveniles can be identified more easily because of distinct physical markings (Jiménez-Valverde & Lobo 2006).

The composition of the mature spiders in an assemblage may differ from the composition of the assemblage that includes both immature and mature individuals owing, for instance, to differential phenologies (time of maturity) or mortality rates across species. Thus the exclusion of unidentified immature spiders may affect the results of analyses, both within one habitat (Jiménez-Valverde & Lobo 2006) and when comparing assemblages between habitats.

We used a study comparing spiders in orchards and adjacent deciduous forest (Sackett et al. In press) to test if the results of analyses change with the inclusion or exclusion of immature spider specimens in the data. After the collection of foliage-dwelling spiders, we reared the juveniles until maturity to allow species level identification. We analyzed two datasets: one with only spiders collected as mature individuals (“mature-only” dataset), and the other also containing the extra data obtained from the rearing and identification of immature

spiders (“complete” dataset). The parameters of species richness, evenness, and community composition were calculated using each dataset and the results from the analyses were compared.

The collections of foliage-dwelling spiders were from four apple orchards and adjacent deciduous forests, sampled on three to five occasions from May to August 2004. Three orchards (A, B, and C) were in Frelighsburg (45°03'N, 72°50'W), Québec, on an Agriculture and Agri-Food Canada experimental farm. These orchards and their adjacent forests were sampled on 17–19 May, 7–8 June, 30 June–3 July, 19–22 July, and 9–11 August. Orchard D was an organic commercial orchard in Mt. St. Hilaire (45°31'N, 73° 09'W), Québec, and this orchard and its adjacent forest were sampled during the last three sampling periods listed above. No insecticides had been used in any of the orchards for at least nine years. Apple trees and forest foliage were sampled by beating branches over a 1-m² collecting sheet. In the Frelighsburg orchards we sampled trees from the two outer rows: 16 apple trees, 5 branches per tree, whilst in the Mt. St. Hilaire orchard we sampled interior trees, not edge trees, due to constraints from other research projects. In the adjacent forest, we sampled the foliage of two 5-m blocks along the edge (1 m into the forest).

To include as many immature specimens as possible in the complete dataset, we used two strategies to identify these individuals. Some species were identified even when immature from non-reproductive characteristics: *Araniella displicata* (Hentz 1847), *Enoplognathia ovata* (Clerck 1757), *Philodromus rufus vibrans* Dondale 1964, *Misumenavatia* (Clerck 1757) and *Tmarus angulatus* (Walckenaer 1837). Other immature spiders were reared individually in the laboratory on a diet of live *Drosophila* until reproductively mature and then identified. To increase rearing success during the latter portion of the study, the *Drosophila* were fed diet supplemented with ground dog food (Nutro: Natural Choice, Nutro Products Inc., California); the spiders were also fed various insects collected from outdoors. Spider nomenclature followed that of Platnick (2007), and vouchers were deposited in the Lyman Entomological Museum of McGill University (Ste.-Anne-de-Bellevue, Québec).

³Corresponding author. Current address: Department of Ecology and Evolutionary Biology, University of Tennessee, 569 Dabney Hall, 1416 Circle Drive, Knoxville, Tennessee 37996, USA. E-mail: tsackett@utk.edu

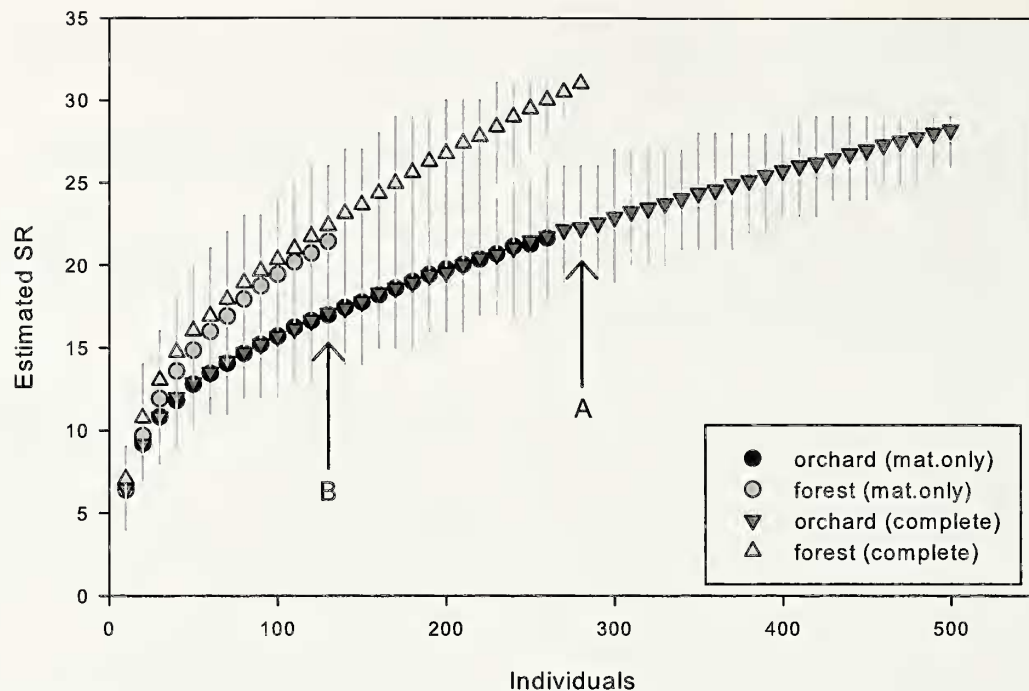


Figure 1.—Individual-based rarefaction curves depicting estimated spider species richness (SR) ($\pm 95\%$ confidence intervals) for orchard and forest habitats in southern Québec using complete and mature-only (“mat.only”) datasets. Arrows indicated species richness at which orchard and forest was compared for complete dataset (A) and mature-only dataset (B).

To estimate species richness in each habitat and with each dataset, we calculated individual-based rarefaction curves using Ecosim version 7, with an independent algorithm and 1000 iterations per abundance level (Gotelli & Entsminger 2004). First, we compared the rarefied species richness of each habitat from each dataset. Then we assessed whether comparisons of species richness between habitats would differ depending on which dataset was used.

We compared the evenness of the individuals among species in the two datasets with Whittaker rank-abundance plots, separating the data by habitat and dataset and expressing the relative abundance (log transformed) of each species as a percent of the total abundance (Magurran 2004).

We assessed differences between the species composition of the samples based on location (A, B, C, or D), habitat (orchard or forest), and dataset (complete or mature-only). To compare samples we used non-metric multidimensional scaling (NMDS), a non-parametric ordination method that does not require linear relationships between variables (McCune & Grace 2002). We log transformed the abundance data to reduce the influence of common species. To eliminate the effect of different total abundances in each dataset, we expressed species abundance values as a percent of total abundance in each dataset. Both transformations and standardizations of data are acceptable before analysis using NMDS (McCune and Grace 2002). Using PCORD v. 4 (McCune & Mefford 1999), we did an initial six-dimensional analysis (parameters: Sørensen distance measure, random starting configuration, 100 iterations, 50 runs with real data, and 100 runs with randomized data (Monte Carlo test)). For the second run we altered the number of dimensions to that recommended by the preliminary run and used the graph coordinates from this preliminary run as the starting coordinates (McCune & Grace 2002).

Forty percent of the immature spiders were successfully reared. Mortality of juveniles occurred mainly during the early rearing period, when spiders were fed fruit flies without a supplemented diet (i.e., added dog food). The success rate of rearing was over 80% when spiders were fed fruit flies reared with supplemented diet.

Identifying immature spiders doubled the number of identified individuals included in the analyses from 402 to 809, and the number of species identified increased from 35 to 43. Of these eight species not represented by mature specimens, six were singletons, one species, *Emblyna maxima* (Banks 1892), was only found occasionally (12 specimens), but another species, *Philodromus praelustris* Keyserling 1880, was one of the most common species found in the study (129 specimens). A complete species list is available in Sackett et al. (in press).

Despite the increase in raw species richness when the complete dataset was used, rarefied estimations of species richness in each habitat (orchard and forest) were the same when calculated using either dataset (Figure 1). The inclusion of data obtained from rearing and identifying immature specimens produced the same results as an increase in sampling effort would have done. When the rarefied species richness of orchard and forest were compared using the complete dataset, the forest had significantly more species than the orchard because the 95% confidence intervals calculated by EcoSim did not overlap (Fig. 1, point A). This significant difference between the species richness of the two habitats was not found from the rarefaction of data from the mature-only dataset (Fig. 1, point B); this was due to fewer individuals (lower sampling effort) in the dataset rather than changes in the rarefaction curves. Jiménez-Valverde & Lobo (2006) also found that low sample sizes from the exclusion of juveniles negatively affected the precision of species richness estimators, but in contrast to our study, the value of species richness estimators differed between datasets that included or excluded juveniles.

There was a more even distribution of individuals among species (rank abundance) in both orchard and forest habitats in the complete dataset as compared to the mature-only dataset (Fig. 2). These differences could either reflect compositional differences in the assemblages or lower sampling effort.

The NMDS comparing samples from each location, habitat, and dataset produced a two-dimensional ordination (final stress = 6.48) explaining 93.5% of the variation (axis 1: $R^2 = 0.796$; axis 2: $R^2 =$

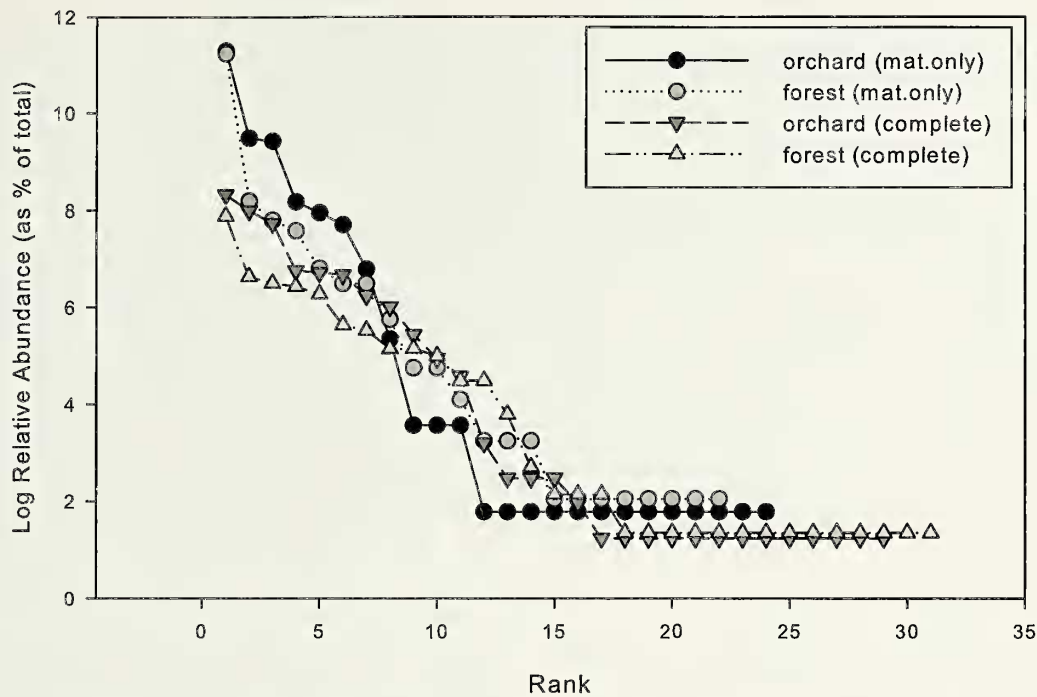


Figure 2.—Rank-abundance (Whittaker) plot of relative abundance of spider species (\log_{10} abundance, expressed as percent of total) in orchard and deciduous forest in Southern Québec and from complete and mature only (“mat.only”) datasets.

0.139). In general, the two points from each particular habitat and location were close, indicating that the composition of the assemblages was similar regardless of dataset (Fig. 3).

Sample points from the mature-only dataset tended to be below and to the left of all sample points from the complete dataset. This consistent shift in space suggests that there is also a consistent change in the sample composition between datasets. Since samples were

standardized so that there was no difference in abundance between datasets, the main difference between the samples was the number of species and evenness, both of which were higher in samples in the complete dataset. Again, the different results from the two datasets appear to be because of a relative difference in sampling effort, rather than variations in species composition resulting from the exclusion of immature specimens.

In our study the results of community analyses were the same when data from immature specimens was included or excluded, and an increase in sampling effort would produce a comparable increased precision of the analyses. The similarity of assemblages between habitats was largely determined by the dominant species within the habitats, and these species were collected as mature individuals. Rearing immature spiders also required considerable time, space, and effort. Jiménez-Valverde & Lobo (2006) showed that species richness estimates of a spider community in central Spain were altered by the exclusion of juveniles. These different results could be due to biological differences between the communities, or statistical differences between datasets. For example, the inclusion of juveniles increased the number of individuals by about ten-fold in the data of Jiménez-Valverde & Lobo (2006), but only doubled the number of individuals in our study. Although in our system the inclusion of immature spiders was unnecessary for accurate comparisons of community parameters between habitats, this may not be true for all spider communities.

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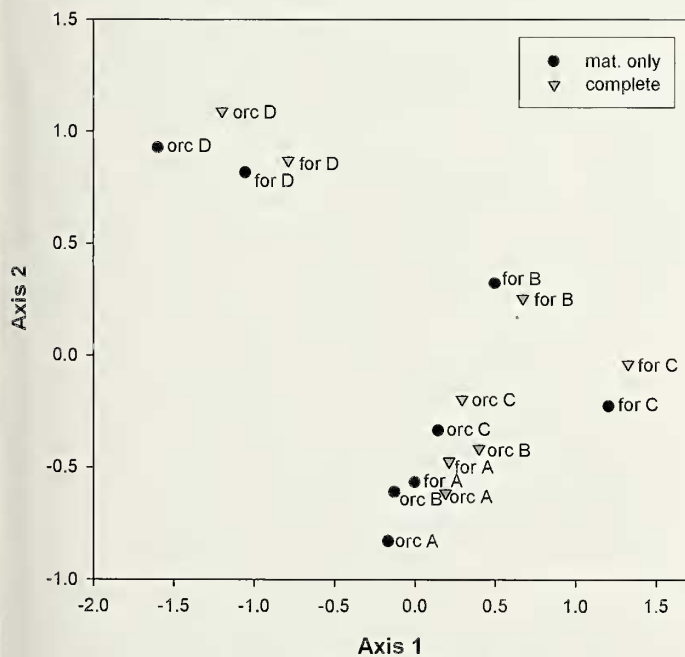


Figure 3.—Sample unit (orchard or forest for each site, collection dates pooled) non-metric multidimensional scaling (NMDS) analysis of southern Québec spider collections from complete and mature-only (“mat.only”) datasets. Labels following symbols indicate habitat (orchard: “orc”, forest: “for”) and site (A to D) of sample.

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LITERATURE CITED

- Bostanian, N.J., C.D. Dondale, M.R. Binns & D. Pitre. 1984. Effects of pesticide use on spiders (Araneae) in Quebec apple orchards. *Canadian Entomologist* 116:663–675.
- Brierton, B.M., D.C. Allen & D.T. Jennings. 2003. Spider fauna of sugar maple and white ash in northern and central New York State. *Journal of Arachnology* 31:350–362.
- Gotelli, N.J. & G.L. Entsminger. 2004. EcoSim. Null models software for Ecology. Version 7.0. Acquired Intelligence Inc. & Kesey-Bear, Jerico, Vermont. Online at <http://www.garyentsminger.com/ecosim/index.htm>.
- Jiménez-Valverde, A. & J.M. Lobo. 2006. Establishing reliable spider (Araneae, Araneidae and Thomisidae) assemblage sampling protocols: estimation of species richness, seasonal coverage and contribution of juvenile data to species richness and composition. *Acta Oecologica* 30:21–32.
- Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Science, Oxford, UK. 268 pp.
- Mason, R.R., D.T. Jennings, H.G. Paul & B.E. Wickman. 1997. Patterns of spider (Araneae) abundance during an outbreak of western spruce budworm (Lepidoptera: Tortricidae). *Environmental Entomology* 26:507–518.
- McCune, B. & J.B. Grace. 2002. *Analysis of Ecological Communities*. MjM software design, Gleneden Beach, Oregon. 300 pp.
- McCune, B. & M.J. Mefford. 1999. PC-ORD v. 4. Multivariate analysis of ecological data. MjM Software Design, Gleneden Beach, Oregon.
- Olszak, R.W., J. Luczak, E. Niemczyk & R.Z. Zajac. 1992a. The spider community associated with apple trees under different pressure of pesticides. *Ekologia Polska* 40:265–286.
- Olszak, R.W., J. Luczak & R.Z. Zajac. 1992b. Species composition and numbers of spider communities occurring on different species of shrubs. *Ekologia Polska* 40:287–313.
- Platnick, N.I. 2007. *The World Spider Catalog*, version 7.5. American Museum of Natural History, New York. Online at <http://research.amnh.org/entomology/spiders/catalog/index.html>.
- Sackett, T.E., C.M. Buddle & C. Vincent. In press. Comparisons of the composition of foliage dwelling spider assemblages in apple orchards and adjacent deciduous forests. *Canadian Entomologist*.
- Samu, F., V. Racz, C. Erdelyi & K. Balazs. 1997. Spiders of the foliage and herbaceous layer of an IPM apple orchard in Keckskemet-Szarkas, Hungary. *Biological Agriculture & Horticulture* 15:131–140.

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